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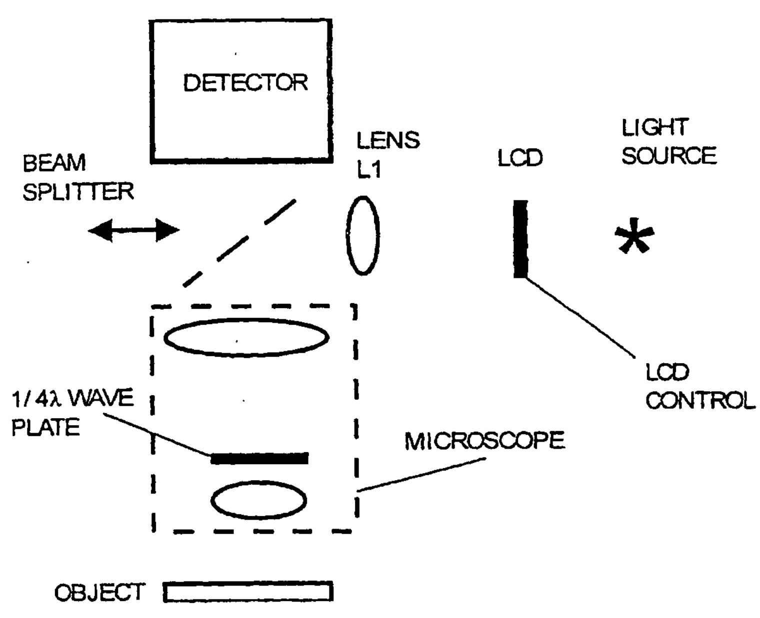
(54) Title: SCANNING MICROSCOPE BY LCD



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(57) **Abstract:** An apparatus for scanning an object comprising a liquid crystal display; a light source optically coupled to said liquid crystal display; a beam splitter optically coupled to said liquid crystal display; an optical microscope optically coupled to said beam splitter; and a quarter wave plate optically coupled to said optical microscope, said quarter wave plate being for transforming linearly polarized light into circularly polarized light.

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

SCANNING MICROSCOPE BY LCD

Field and background of the innovation.

In US 5,381,236, an optical sensor is described which produces three-dimensional images by scanning an object with a periodic pattern. In US 5,867,604, a further development of the periodic pattern scanning technology introduces phase analysis to improve resolution. US 5,867,604 also introduces Liquid Crystal Display as a source for the pattern.

The present innovation provides a method and apparatus for optically coupling a Liquid Crystal Display to a microscope and for scanning with periodic patterns.

Summary of the innovation

Liquid Crystal Displays (LCD) require linear polarized light, which is a major drawback for using such displays in scanning microscopy. Imaging of lines and edges with polarized light will appear deferent if the edge is parallel to the polarization or if it is perpendicular thereto. To solve this problem, according to the present invention a quarter wave plate is added on the optical trail of the light. The quarter wave plate change the linear polarization to circular. Thus the object is illuminated by circular polarization, and therefor the orientation of the edges and other features does not affect the resulting image.

One more problem solved by the present innovation is the high loses of intensity by the beam splitter, which couples the LCD to the microscope. Half of the light intensity is lost when light passes from the LCD to the object and half of the remaining intensity is lost on the way back to the detector. The solution offered by the present invention is using polarized beam splitter. A polarizing beam splitter directs the whole intensity from the LCD to the object without loses or at least with very minute losses. As the circularly polarized light is reflected back from the object, it passes through the quarter wave plate once again on its way to the detector. This time, the quarter wave plate acts to change the circular polarization into linear polarization once again. The linearly polarized light then passes through the polarizing

beam splitter to the detector without intensity losses. The improvement provides four times more light intensity.

The polarizing beam splitter also solves the problem of undesired reflections coming from the surfaces of lenses and other optical components.

reflections of light, which do not pass twice through the quarter wave plate, have a perpendicular polarization, and therefore do not pass through the polarization beam splitter.

Reduction of undesired reflections could also be achieved if the beam splitter is not polarizing. In this case, a polarizer should added to the microscope, which will pass through only light with the proper polarization.

Scanning with periodic pattern requires a very stable light source. Noise originating from the light source itself or from the airflow heated by the light source, creates serious noise problems for the image produced in the scanning process. The present invention introduces Light Emitting Diode

rather than the standard lamps and lasers. The LED offers a very stable, non-heating light source which considerably improves scanning noise problems. If a system requires a heating light source such as an arc lamp, a solution to hot air disturbances is offered by pumping hot air out, or blowing cooler air, e.g., at room temperature, into the trail of the light next to the light source.

Scanning with periodic pattern produces amplitude and phase information. To analyze phase shifts introduced by an object, a calibration of the original phase of the illumination without shifting is required. It is realized that such calibration requires a mirror as a target, because mirrors do not shift the phase. It will be appreciated that replacing the object with a mirror for calibration, and then repositioning the object back to locate the desired targets is cumbersome and inconvenient. The present invention offers an easy solution to this problem. A mirror is constantly attached to one of the objectives mounted on the turret of the microscope and used specifically for calibration. Whenever a calibration is required, the turret is revolved to the calibration objective. When the calibration is satisfactorily completed, it is

revolved back. In this way, a calibration can be performed without moving the object from its location.

Brief description of the drawings:

Fig. 1 is a schematic depiction of the scanning microscope according to a preferred embodiment of the present invention.

Fig. 2 is an image of 0.25 μm semiconductors lines and their three dimensional topography as obtained using the scanning microscope of the present invention.

Fig. 3 is an image of the same 0.25 μm semiconductors lines obtained using a conventional microscope.

Description of the preferred embodiments

In a preferred embodiment, as seen in Fig. 1, light is originated at a light source, passes through a Liquid Crystal Display and is then directed by a beam splitter to the microscope. The microscope projects the image of the Liquid Crystal Display on the object. The lens L1, adjusts the magnification of the Liquid Crystal Display to the magnification of the microscope. In case such adjustment is not required, lens L1 may be redundant. The quarter wave plate change the polarization of the light from linear to circular or elliptic polarization. Light reflected from the object is projected by the microscope upon the sensor. On the way, the light passes through the quarter wave plate, which changes its polarization from circular to linear again. The beam splitter can be a polarizing beam splitter for better light efficiency.

In the configuration of Figure 1, the Liquid Crystal Display is optically coupled to the microscope by the beam splitter at the location between the microscope and a camera.

In a different embodiment, the beam splitter can be in a different location, for example next to the objective. This configuration is more similar to the standard coupling of a microscope to a light source.

The quarter wave plate can be located at any point on the optical path of the light after passing the Liquid Crystal Display. If the quarter wave plate is placed between the Liquid Crystal Display and the beam splitter, then light

will pass it only one way; therefore the image at the sensor will have circular or elliptic polarization. This configuration is also valid according to the present invention.

Lens L1 may become redundant, if there is no need for magnification adjustment of the Liquid Crystal Display.

Example

The capability of three dimensional imaging with liquid crystal display is demonstrated in Figure 2 which shows an image of 0.25 μm semiconductors lines and their three dimensional topography. The standard microscopic imaging of the same lines is shown in Figure 3.

The object was scanned by periodic pattern in two axes x and y with LCD of 640 x 480 pixels. The line pitch of the periodic pattern was 0.6 μm at the object plane, and the pixel size projected upon the object was 0.1 μm. During the scanning, the pattern was shifted in 6 steps in the x-axis and 6 steps in y, 60 degrees phase shift in each step.

For three dimensional imaging, we scanned the object three times. First time, at its best focus, and then below and above the best focus. By analysis of the three images, each one related to a different focal plane, the height of points on the lines could be measured with 12.5 nm resolution.

What is claimed is:

1. An apparatus for scanning an object comprising:
a liquid crystal display;
a light source optically coupled to said liquid crystal display;
a beam splitter optically coupled to said liquid crystal display;
an optical microscope optically coupled to said beam splitter;
a quarter wave plate optically coupled to said optical microscope, said quarter wave plate being for transforming linearly polarized light into circularly polarized light.

2. The apparatus of claim 1, wherein said beam splitter is moveable, thereby allowing fast coupling and decoupling of the liquid crystal display from the microscope.

3. The apparatus of claim 1, wherein said beam splitter is optically coupled with a polarizer.

4. The apparatus of claim 1, wherein said beam splitter is a polarizing beam splitter.

5. The apparatus of claim 1, wherein said quarter wave plate is moveable.

6. The apparatus of claim 1, wherein said liquid crystal display is optically coupled with a lens, said lens adjusts the magnification of the liquid crystal display to the microscope.

7. The apparatus of claim 1, wherein air heated by said light source is pumped out from the trail of light.

8. The apparatus of claim 1, wherein air is blown into the trail of light next to said light source.

9. The apparatus of claim 1, wherein said microscope is coupled to a set of objectives, wherein one objective is coupled to a mirror for calibration.

10. The apparatus of claim 1, wherein said light source is Light Emitting Diode.

11. The apparatus of claim 1, wherein said light source is a set of Light Emitting Diodes.

12. An apparatus for scanning an object comprising:
a device for producing a periodic pattern;
an optical microscope coupled to said device for producing said periodic pattern, wherein said microscope projects said periodic pattern upon the object;
a detector optically coupled to said microscope, wherein said microscope projects an image of said object upon said detector;
a set of objectives optically couplable to said microscope, wherein one of said objectives is optically coupled to a mirror, said mirror being for calibrating said pattern to said detector.

13. An apparatus for scanning an object comprising:
a device for producing a periodic pattern;
a set of Light Emitting Diodes being optically coupled to said device for producing said periodic pattern ;
an optical microscope being optically coupled to said device for producing said periodic pattern, wherein said microscope projects said periodic pattern upon the object;
a detector being optically coupled to said microscope, wherein said microscope projects an image of said object upon said detector.

14. The apparatus of any of claims 11 and 13 wherein, said device for producing said periodic pattern is a Liquid Crystal Display.

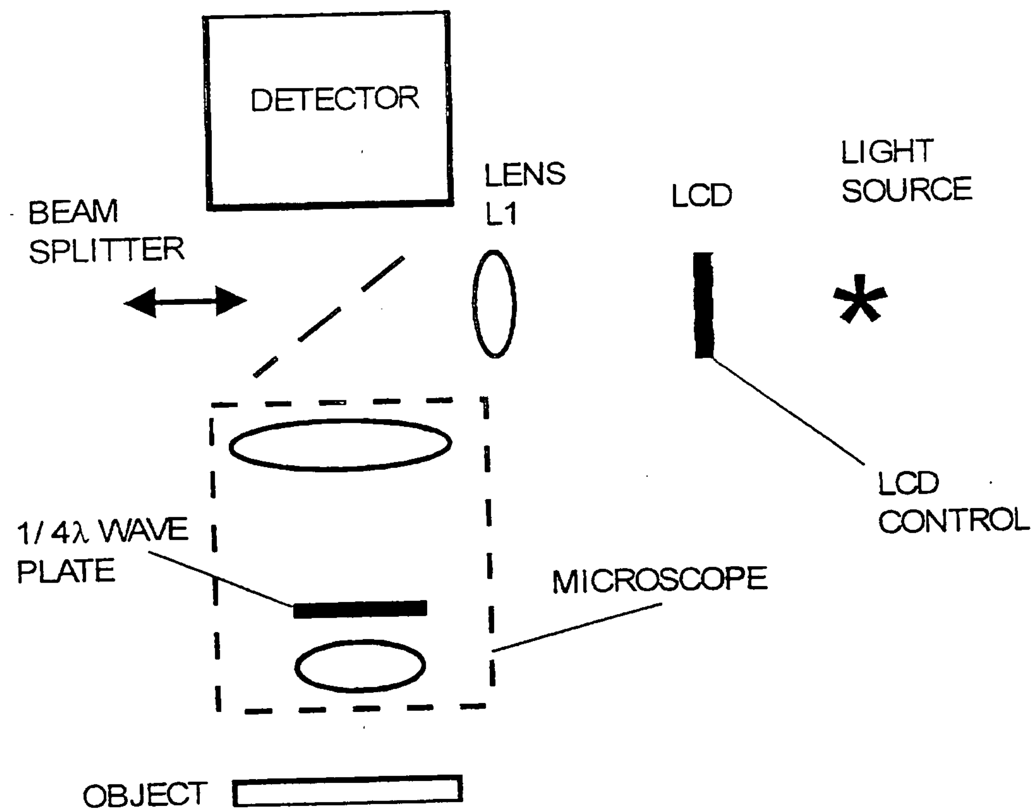
DETECTOR
LENS
L1
LCD
LIGHT
SOURCE
BEAM
SPLITTER
LCD
CONTROL
1/4λ WAVE
PLATE
MICROSCOPE
OBJECT

FIG. 1

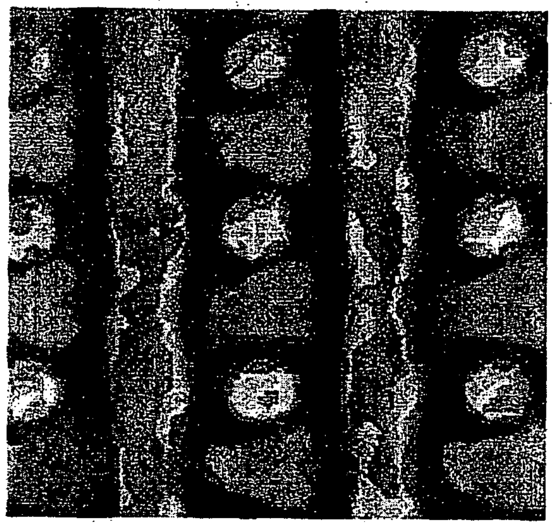

FIG. 2

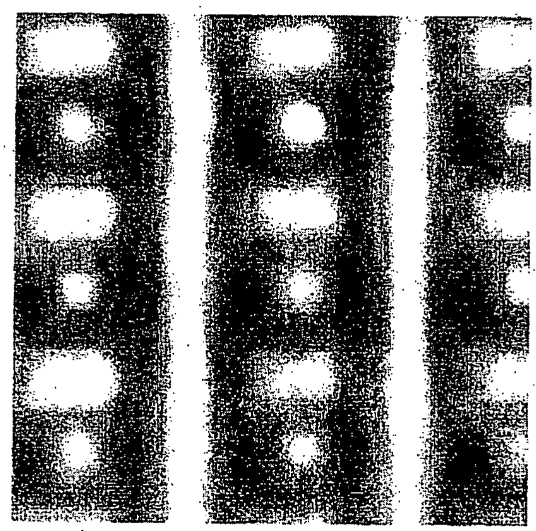

FIG. 3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US00/15773

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) :G02B 21/06
US CL :359/386
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 359/386, 227, 368, 381, 389

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

NONE

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

NONE

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X,P	US 6,031,661 A (TANAAMI) 29 February 2000 (29.02.2000), fig. 7.	1-6, 10-11, 13-14
A	US 5,587,832 A (KRAUSE) 24 December 1996 (24.12.1996), fig. 1.	1-14

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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